Chapter 2

Bicycle Compatible Roadway/Design Treatments

Planning and designing highways to permit the shared use of roadways by bicyclists and motorists usually does not require excessive changes, effort or cost. In most cases, existing roadway widths, space, and surface conditions may be sufficient to allow safe bicycling. Bicycle compatible roadways offer additional benefits to highway users such as:

- Greater offset to fixed objects
- Additional space for disabled vehicles
- Greater recovery zone for errant motorists
- Additional space for bus pull-overs at transit stops
- Better stability of roadway pavement structure
- Additional gutter drainage capacity during rainstorms
- Space for pedestrian travel, especially during snowstorms
- Greater area for temporary snow storage
- Reduction or elimination of drop-off at edge of pavement

Because bicycle compatible roadway improvements are intended for the shared use of all highway users and are not specifically designated for bicycle use, no additional exposure to liability is incurred by the highway agency. A well designed bicycle compatible roadway should reduce accidents and exposure to liability by allowing a safer environment for all highway users.

On the other hand, failure to take reasonable measures to assure that a highway is compatible with bicycle use, even though adequate measures could have been installed, increases an agency's potential exposure to liability in the event of a subsequent accident. The guidelines presented in this chapter thus represent a minimum level of improvement which should be applied during the construction or reconstruction of all roadways in the state.

Bicycle compatible facilities provide access to the transportation system for bicycle traffic and enhance bicycle safety. Most bicycle accidents do not involve crashes with motor vehicles. Bicyclists instead lose control of their vehicles and crash. Roadways not designed or properly maintained to address the needs of bicycle traffic can contribute to these accidents. Properly designed and maintained roadways mitigate bicycle safety problems and lessen the chance of these accidents.

The more common bicycle accidents which do involve motor vehicles, such as vehicles turning or merging into the path of the bicyclist, motorist failure to yield to bicycle traffic, or bicyclist failure to yield, can also be reduced through proper roadway design which accommodates bicycle use.

1. Pavement Width

At a minimum, all highway projects shall provide sufficient width of smoothly paved surface to permit the shared use of the roadway by bicycles and motor vehicles.

Table 1 is based on the FHWA manual, Selecting Roadway Design Treatments to Accommodate Bicycles, as well as previous experience in New Jersey and other states. Pavement widths represent minimum design treatments for accommodating bicycle traffic. These widths are based on providing sufficient pavement for shared use by bicycle and motor vehicle traffic and should be used on highway projects as minimum guidelines for bicycle compatible roadways.

Considerations in the selection of pavement width include traffic volume, speed, sight distance, number of trucks and larger vehicles, and grade. The dimensions given in Table 1 for shared lanes are exclusive of the added width for parking, which is assumed to be 2.4 meters (8 feet). On shared lanes with parking, the lane width can be reduced if parking occurs only intermittently. On travel lanes where curbs are present, an additional 0.3 meters (1 foot) of width is necessary.

On very low volume roadways, having an AADT of less than 1200 vehicles per day, even relatively fast highways pose little risk for bicyclists since there will be high probability that an overtaking car will be able to widely pass a bicyclist. When an overtaking car is unable to immediately pass a bicyclist, a small delay for the motorist will be acceptable. These types of roadways are enjoyed by both bicyclists and motorists, and widening of these roads is not usually recommended. Cost of providing widening of these roads can seldom be justified based on either capacity or safety.

Similarly, moderately low volume roadways having an AADT between 1,200 and 2,000 generally are compatible for bicycle use and will have little need for widening. However, since there is a higher risk of two opposing cars meeting at the same time, and as motorists must pass a bicyclist, providing some room at the outside of the roadway is desirable on faster speed roadways. On low speed roadways, motorists should be willing to accept some minimal delay.

With AADT greater than 2,000, the probability becomes substantially greater that a vehicle overtaking a bicycle may also meet another on-coming vehicle. As a result, on these roads, some room at the edge of the roadway should be provided for bicyclists. At low speeds, little separation is needed for both a bicyclist and a motorist to feel comfortable during a passing event. With higher speeds, more room is needed.

At volumes greater than 10,000 AADT, vehicle traffic in the curb lane becomes almost continuous, especially during peak periods. As a result bicyclists on these roads require separate space to comfortably ride. In addition, improvements to the roadside border and the shoulder area will be especially valuable for motorists as well.

NJDOT guidelines for highways recommend that a full 2.4 meter (8 foot) paved shoulder be provided for all state highways. On highways having an AADT greater than 20,000 vehicles per day, or on which more than 5 percent of the traffic volume consists of trucks, every effort should be made to provide such a shoulder, both for the benefit of bicyclists and to enhance the safety of motor vehicle movement.

Table 1

Bicycle Compatible Roadway Pavement Widths

Condition I
AADT 1200 -2000*

	URBAN W/PARKING	URBAN W/O PARKING	RURAL
<50 km/h (30 mph)	SL 3.6m (12 ft.)	SL 3.3m (11 ft.)	SL 3.0m (10 ft.)
50 km/h-65 km/h (31-40 mph)	SL 4.2m (14 ft.)	SL 4.2m (14 ft.)	SL 3.6m (12 ft.)
65 km/h-80 km/h (41-50 mph)	SL 4.5m (15 ft.)	SL 4.5m (15 ft.)	SH 0.9m (3 ft.)
>80 km/h (50 mph)	NA	SH 1.2m (4 ft.)	SH 1.2m (4 ft.)

* For volumes less than 1200 a shared lane is acceptable.

KEY: SH=shoulder SL=shared lane

Condition II
AADT 2000-10,000

	URBAN W/PARKING	URBAN W/O PARKING	RURAL
<50 km/h (30 mph)	SL 4.2m (14 ft.)	SL 3.6m (12 ft.)	SL 3.6m (12 ft.)
50 km/h-65 km/h (31-40 mph)	SL 4.2m (14 ft.)	SL 4.2m (14 ft.)	SH 0.9m (3 ft.)
65 km/h-80 km/h (41-50 mph)	SL 4.5m (15 ft.)	SL 4.5m (15 ft.)	SH 1.2m (4 ft.)
>80 km/h 50 mph	NA	SH 1.8m (6 ft.)	SH 1.8m (6 ft.)

Condition III
AADT over 10,000 or Trucks over 5%

	URBAN W/PARKING	URBAN W/O PARKING	RURAL
<50 km/h (30 mph)	SL 4.2m (14 ft.)	SL 4.2m (14 ft.)	SL 4.2m (14 ft.)
50 km/h-65 km/h (31-40 mph)	SL 4.2m (14 ft.)	SH 1.2m (4 ft.)	SH 1.2m (4 ft.)
65 km/h-80 km/h (41-50 mph)	SL 4.5m (15 ft.)	SH 1.8m (6 ft.)	SH 1.8m (6 ft.)
>80 km/h (50 mph)	NA	SH 1.8m (6 ft.)	SH 1.8m (6 ft.)

NOTE: NJDOT minimum shoulder width of 2.4 meters (8 feet) should be provided wherever possible on roadways having an AADT greater than 10,000 vehicles.

a. Conditions Where Additional Space is Warranted

- **Sight Distance**

Roadways with adequate decision sight distance will allow a motorist to see, recognize, decide on the proper maneuver, and initiate actions to avoid a bicyclist. Adequate decision sight distance is most important on high speed highways and narrow roadways where a motorist would have to maneuver out of the travel lane to pass a bicyclist.

The pavement widths given in Table 1 are based on the assumption that adequate sight distance is available. In situations where there is not adequate sight distance, additional widths may be necessary.

- **Truck Traffic**

Roadways with high volumes of trucks and large vehicles, such as recreational vehicles, need additional space to minimize bicycle/motorist conflicts on roadways. Additional width will allow overtaking of bicycles by trucks with less maneuvering. Additionally, overtaking by a truck will exert less lateral force from truck drafts, and provide greater sight distance for following vehicles.

Although there is no established threshold, additional space should be considered when truck volumes exceed 5 percent of the traffic mix, or on roadways that service campgrounds or tourist travel. Where truck volumes exceed 15 percent of the total traffic mix, widths shown in the table should be increased by a minimum of 0.3 meters (1 foot).

- **Steep Grades**

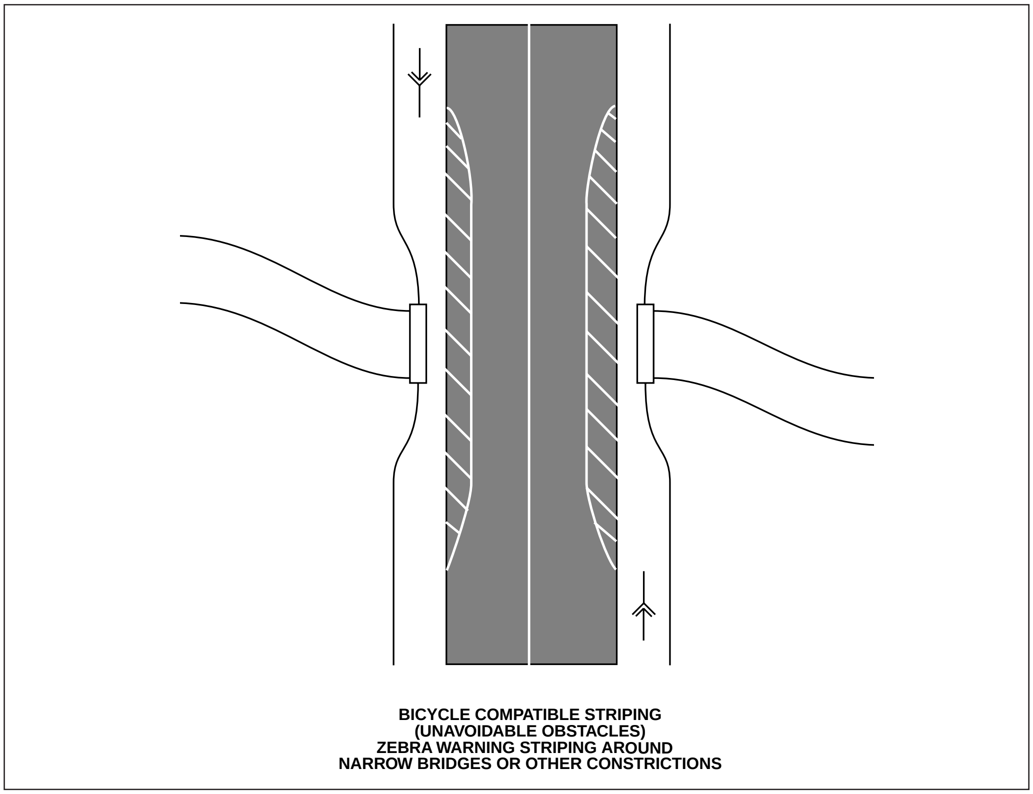
Steep grades influence overtaking of bicyclists by motorists. A bicyclist climbing a steep grade is often unsteady and should be afforded additional width. Also, the difference in speed of a slow, climbing bicyclist and motorist results in less time for a vehicle to maneuver around a bicyclist. The slowing of a motor vehicle on a steep grade to pass a bicyclist can result in diminished highway level of service.

A bicyclist descending a steep grade may also need more width. A high speed bicyclist will tend to move into the travel lane to avoid roadside hazards. Where descending grades exceed 6 percent, and bicycle traffic is anticipated, signing should be placed along the descending lane to advise bicyclists and alert motorists of bicyclists in the travel lane (see Section 5 - Traffic Control Devices).

Additional space should be considered on the ascending lane when the grade exceeds 3 percent. Where the grade exceeds 5 percent, a minimum of a 1.5 meter (5 foot) wide shoulder or 4.8 meter (16 foot) wide curb lane in urban conditions is desirable to afford safe shared use with minimal impact on level of service.

b. Treatment for Unavoidable Obstacles

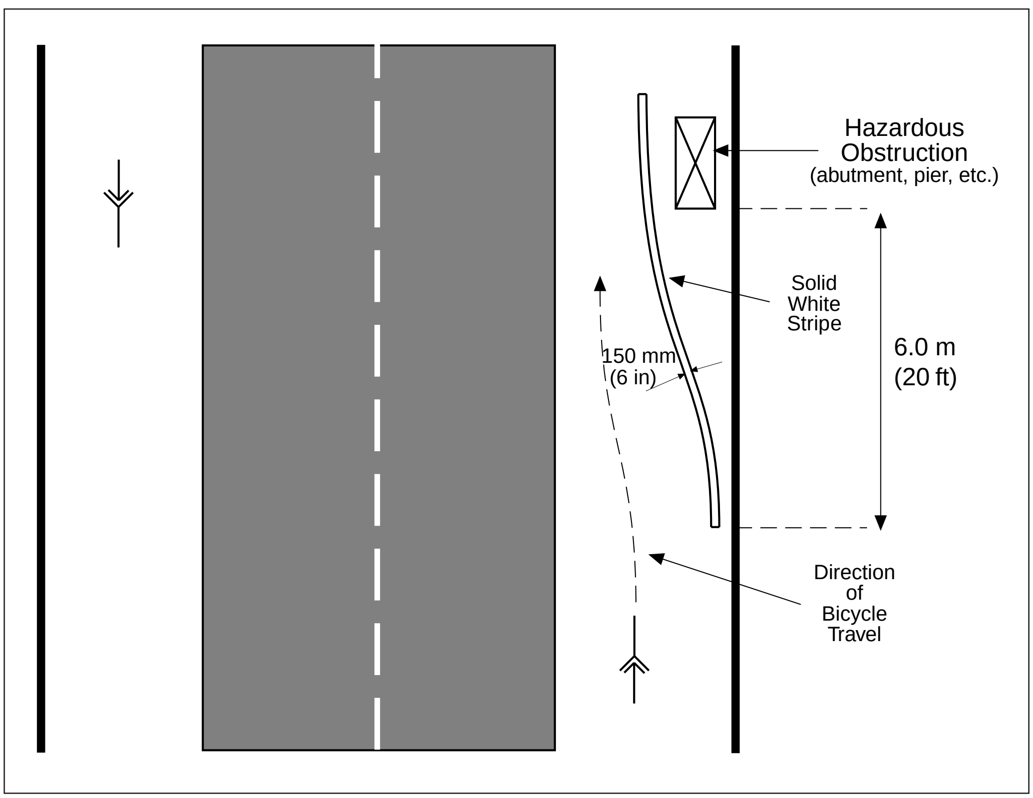
Short sections of roadways with unavoidable obstacles that result in inadequate width are acceptable on bicycle compatible roadways if mitigated with signing or striping. Typical examples include bridges with narrow widths and sections of roadway that cannot be widened without removing significant street trees. These conditions preferably should not exist for a distance greater than 0.4 kilometers (one quarter mile) or on high speed highways. Zebra warning striping should be installed to shift traffic away from the obstacle. See Figure 3. Figure 4, Bicycle Compatible Hazard Marking, is another option when an obstacle cannot be removed. In this case pavement markings alert the bicyclist that the travel lane width will narrow. In both situations, where bicycle traffic is anticipated, a share the road sign should be used to supplement any striping. See Figure 5 - Share the Road Sign. On longer sections of roadway, edge striping should be added to narrow the travel lane and apportion pavement space for a partial shoulder.



Source: Adapted from NJDOT Bicycle Compatible Roadways, NJDOT, 1982

Figure 3

Zebra Warning Striping



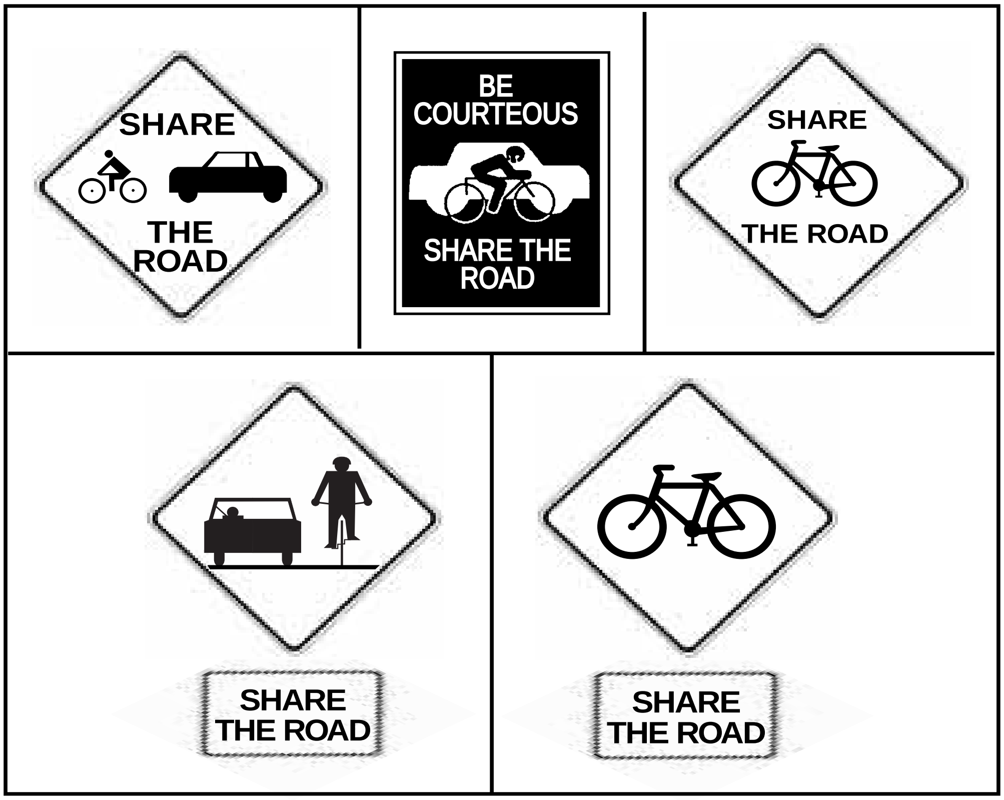
Source: Adapted from Bicycle Compatible Roadways, NJDOT, 1982

Figure 4

Bicycle Compatible Hazard Marking

Figure 5

Share the Road Sign



Source: Bicycle Federation of America

NOTE: These represent examples of signs used by others. NJDOT is in the process of adopting an approved sign.

2. Pavement Design

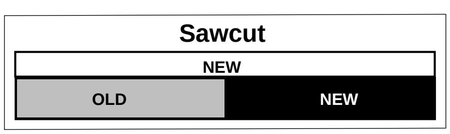
With their narrow, high pressure tires, and lack of suspension, bicycles require a smooth riding surface without obstructions or pavement irregularities. On roadways with rough surfaces and hazards, a bicyclist will ride as close to the smooth wheel track in the travel lane as possible. These conditions will affect the level of service of the roadway.

a. Pavement Surface

Where shoulders are employed to provide the pavement width necessary to accommodate bicycle traffic, pavement surface should be as smooth as the adjacent travel lane. Bituminous concrete is preferred over concrete where shoulders are employed. The outside pavement area (where bicycle traffic normally operates) should be finished free of longitudinal seams. On portland cement concrete, pavement transverse expansion joints (if necessary) should be sawcut to ensure a smooth ride.

Figure 6

Pavement Joints



Source: NJDOT

In areas where bituminous shoulders are added to existing pavement, or pavement is widened, pavement should be sawcut to produce a tight longitudinal joint. The pavement section at the sawcut should match the existing section to minimize wear and opening of the joint. See Figure 6.

b. Rumble Strips

Rumble strips provide positive guidance for motorists on freeways. However, they present a difficult obstruction and potential hazard to bicyclists. Use of rumble strips should be avoided on all land service roadways.

c. Raised Roadway Reflectors

Raised roadway reflectors provide substantial benefits in areas of poor visibility. However, when used on the edge line they are a surface irregularity which can be hazardous to bicycle traffic. Therefore, raised reflectors should only be used along interior lane lines or center lines, not edge lines.

d. Utilities

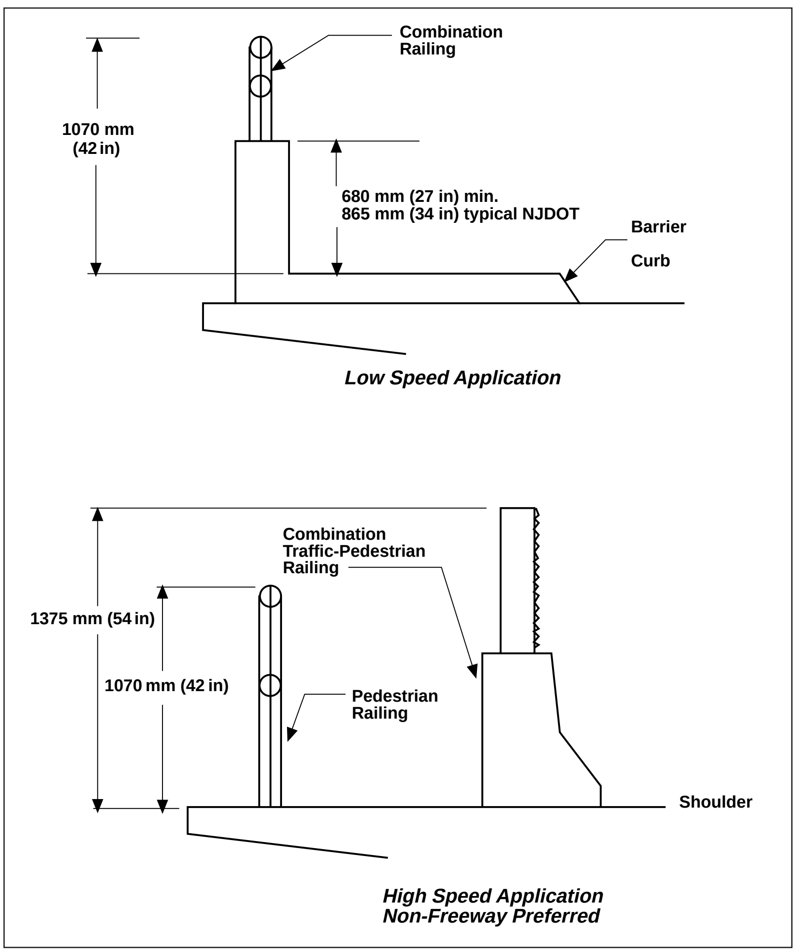
Bicycle traffic is more sensitive to pavement irregularities than is motor vehicle traffic. During construction, appurtenances should not be left projecting above the pavement surface. Repeated resurfacings without adjusting the utility cover neck flange or drainage grate frames results in the covers being sunken below the pavement surface, a hazardous condition to bicycle traffic which bicyclists refer to as "black holes." Therefore, utility covers and drainage grates should be adjusted to fit flush with the roadway surface in all new construction, reconstruction and resurfacing projects.

3. Bridges

Bridges serve an important function by providing bicycle access across barriers. However, some features found in bridges can be unsuitable where bicyclists are to be accommodated. The most common of these are curb-to-curb widths that are narrower than the approach roadways (especially where combined with relatively steep grades), open grated metal deck (found on many movable spans), low railings or parapets and certain types of expansion joints that can cause steering difficulties.

Sidewalks are generally not acceptable for bicycling. However, in a few limited situations, such as on long or narrow bridges, designation of the sidewalk as an alternate facility can be beneficial provided that curb cuts and appropriate signing are provided.

Bridge railing or barrier curb parapets should have railings at least 1.4 meters (4.5 feet) high as shown in Figure 7.



Source: NJDOT

Figure 7

Bicycle Accommodations on Bridges (Bridge Railing or Barrier Curb Parapet Treatments)

4. Drainage Facilities

Stormwater drainage facilities and structures are usually located along the edge of roadway where they often present conflicts with bicyclists. Careful consideration should be given to the location and design of drainage facilities on bicycle compatible roadways.

a. Drainage Inlets and Grates

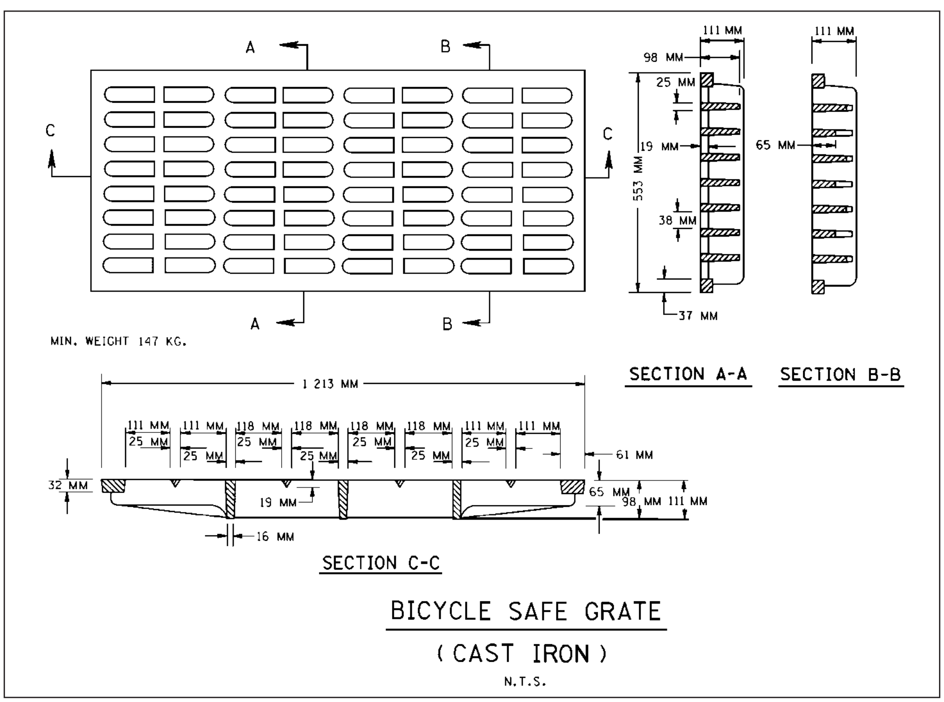
All drainage grate inlets pose some hazard to bicycle traffic. The greatest hazard comes from stream flow drainage grates which can trap the front wheel of a bicycle and cause the cyclist to lose steering control or have the narrow bicycle wheels drop into the grate. A lesser hazard is caused by bicyclists swerving into the lane of traffic to avoid any type of grate or cover.

A "bicycle safe" drainage grate with acceptable hydraulic characteristics has been developed by NJDOT's drainage section (Figure 8). This inlet grate should be used in all normal applications and should be installed flush with the final pavement. Where additional drainage inlet capacity is required because of excessive gutter flow or grade (greater than 2 percent), double inlets should be considered. Depressed grates and stream flow grates should <u>not</u> be used except in unique or unusual situations which require its use and <u>only</u> outside the lane sharing area. Where necessary, depressed grates should only be installed in accordance with the NJDOT Roadway Design Manual on shoulders 1.8 meters (6 feet) wide or greater. Where projects offer the possibility for replacement of stream flow grates located in the lane sharing area, these grates should be replaced with the "bicycle safe" grate.

When roads or intersections are widened, new bicycle safe drainage grates should be installed at a proper location at the outside of the roadway, and existing grates and inlet boxes should be properly retired and removed, and the roadway reconstructed. Drainage grate extensions, the installation of steel or iron cover plates or other "quick fix" methods which allow for the retention of the subsurface drain inlet are unacceptable measures since they will create a safety hazard in the portion of the roadway where bicyclists operate.

Figure 8

NJDOT "Bicycle Safe" Drainage Grate



Source: Standard Roadway Construction Details, NJDOT

b. Manholes and Covers

Manholes and covers should be located outside of the lane sharing area wherever possible. Utility fixtures located within the lane sharing area or any travel lane used by bicycle traffic should be eliminated or relocated. Where these fixtures cannot be avoided the pavement surface should be made flush with the particular facility.

c. Combination Curb and Gutter

These types of curbs greatly reduce space available for bicyclists. They should only be used on low volume streets or where grades dictate special drainage conditions. The width of the gutter pan should not be used when calculating the width of pavement necessary for shared use by bicyclists. On steep grades, the gutter should be set back an additional 0.3 meters (one foot) to allow space to avoid high speed crashes caused by the longitudinal joint between the gutter pan and pavement. In general, the combination curb and gutter is not recommended. Where it is used, pavement width should be calculated by adding 0.3 meters (one foot) from the curbed gutter.

5. Traffic Control Devices

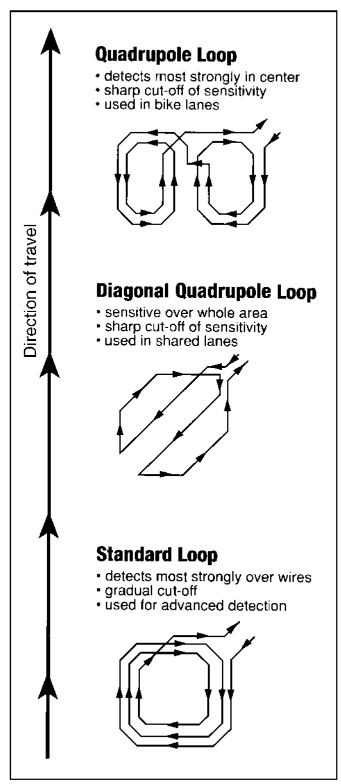
As legitimate users of New Jersey's roadways, bicyclists are subject to essentially the same rights and responsibilities as motorists. In order for bicyclists to properly obey traffic control devices, those devices must be selected and installed to take into account their needs. All traffic control devices should be placed so they can be observed by bicyclists who are properly positioned on the road. This includes programmed visibility signal heads.

a. Traffic Signals and Detectors

Traffic-actuated signals should accommodate bicycle traffic. Detectors for traffic-activated signals should be sensitive to bicycles and should be located in the bicyclist's expected path. Examples of successful installation of bicycle sensitive signal detectors, are shown in Figure 9.

Stenciling should direct cyclists to the point where their bicycle will set-off detectors.

For the sake of riders who have vehicles with insufficient amounts of iron to be detected, and to add redundancy in the event of failure of the bicycle sensitive loop detectors, pedestrian push buttons should be provided at all signalized intersections and mounted in a location which permits their activation by a bicyclist without dismounting. Where left turn lanes are provided and only protected left turns are allowed, bicycle sensitive loop detectors should be installed in the left turn lane or a pedestrian style push button should be provided accessible to a bicyclist in the turn lane to permit activation of the left turn phase.



Source: City of San Diego Traffic Signal BicycleDetection Study, 1985

Figure 9

Recommended Loop Types for Bicycle Detection

Where moderate or heavy volumes of bicycle traffic exist or are anticipated, bicycles should be considered in the timing of the traffic signal cycle as well as in the selection and placement of the traffic detector device. In such cases short clearance intervals should not be used where bicyclists must cross multi-lane streets. According to the 1991 AASHTO Guide for the Development of Bicycle Facilities, a bicycle speed of 16 km/h (10 mph) and a perception/ reaction time of 2.5 seconds can be used to check the clearance interval. Where necessary, an all-red clearance interval can be used.

b. Signing

Bicycle compatible roadways usually do not require regulatory, guide or informational signing in excess of that necessary for motorists, i.e., exclusively for bicyclists. In certain situations, however, additional signing may be needed to advise both motorists and bicyclists of the shared use of the roadway, including travel lane.

Share the Road: This sign (see Figure 5) is intended for use on roadways under the following conditions:

- Shared lanes (especially if lane widths do not comply with Table 1) with relatively high posted travel speeds of 65 km/h (40 mph) or greater.
- Shared lanes (conforming with Table 1) in areas of limited sight distance.
- Situations where bicycle compatible shared lanes or demarcated shoulders or marked bike lanes are dropped or end, and bicycle and motor vehicle traffic must begin to share the travel lane.
- Other situations where it is determined advisable to alert motorists of the likely presence of bicycle traffic, and to alert all traffic of the need to share available roadway space.

Allowed use of Full Lane: This sign (Figure 10) is intended to advise motorists and bicyclists that bicycle traffic may be expected to move to the center of the travel lane in order to increase its visibility or avoid roadway obstacles in certain situations. These conditions include:

Figure 10
“Allowed Use of Full Lane” Sign

Source: Bicycle Blueprint, 1993

- Steep descending grades where bicycle traffic may be operating at higher speeds and requires additional maneuvering room to shy away from pavement edge conditions.
- Steep ascending grades, especially where there is no paved shoulder or the shared lane is not adequately wide; bicycle traffic may require additional maneuvering room to maintain balance at slow operating speeds.
- High volume urban conditions especially those with travel lanes less than the recommended width for lane sharing.

Note: Though not formally adopted by NJDOT, this sign has been used to advise motorists that under certain conditions bicycle traffic can be expected to operate in the center of the travel lane, and is included here to highlight this concept of bicyclists “taking the lane.”

6. Intersections and Driveways

Sand, gravel and other debris in the bicyclist's path present a potential hazard. In order to minimize the possibility of debris from being drawn onto the pavement surface from unpaved intersecting streets and driveways, during new construction, reconstruction and resurfacings, all unimproved intersecting streets and driveways should be paved back to the right-of-way line or a distance of 3.0 meters (10 feet) (Figure 11). Similarly, where curb cuts permit access to roadways from abutting unpaved parking lots, a paved apron should be paved back to the right-of-way line or 3.0 meters (10 feet) from the curb line. These practices will lessen the need for maintenance debris removal. The placement of the paved back area or apron should be the responsibility of those requesting permits for access via curb cuts from driveways and parking lots onto the highway system.

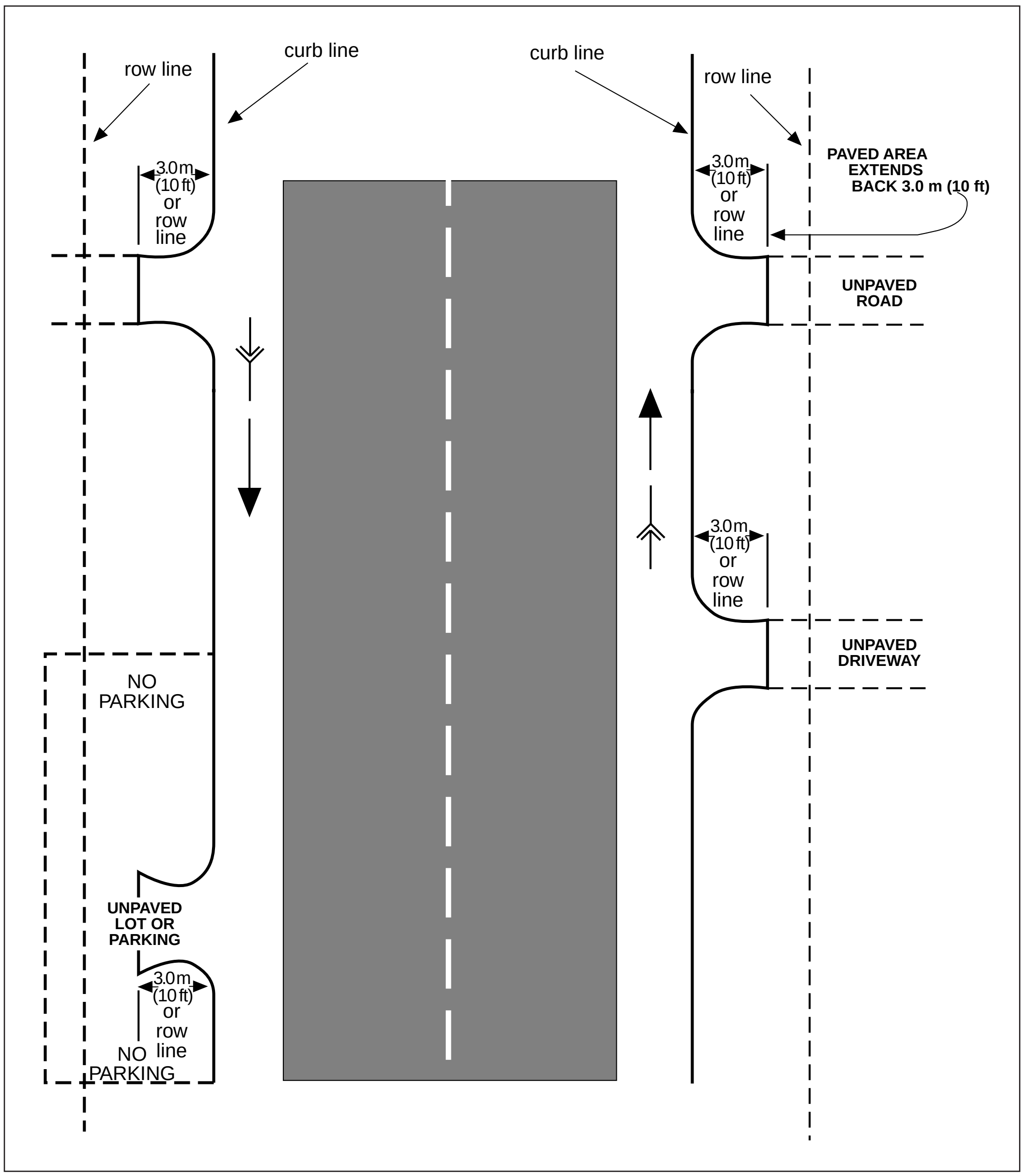


Figure 11

Bicycle Compatible Intersection with Unpaved Streets and Driveways

Source: Adapted from Bicycle Compatible Roadways, NJDOT, 1982

High speed, wide radius intersection designs may enhance safety for motor vehicles by minimizing speed differentials between entering and exiting vehicles and through vehicles. However, these designs exacerbate speed differential problems faced by bicyclists travelling along the right side of a highway and encourage drivers to fail to yield the right-of-way to bicyclists. As a result, where wide radius curb returns are being considered, specific measures should be employed to ensure that the movement of bicyclists along the highway will be visible to motorists and to provide bicyclists with a safe area to operate. One method to accomplish this would be to stripe (dash) a bicycle lane through the intersection area. In this event, share the road signs should be posted in advance of the intersection to alert existing traffic, and yield to bicyclist signs should be posted on the approach to the intersection. In general, however, curb radii should be limited to distances which communicate to the motorist that he or she must yield the right-of-way to bicyclists traveling along the roadway or to pedestrians walking along the sidewalk or roadway margin.

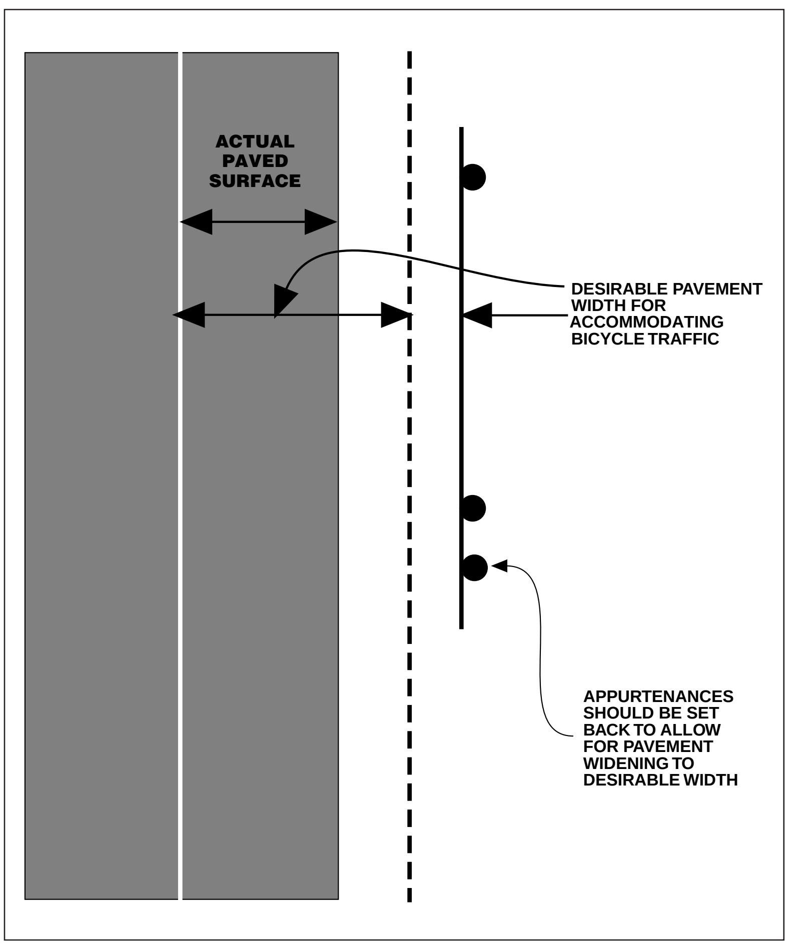
7. Roadside Obstacles

In order to make certain that as much of the paved surface as possible is usable by bicycle traffic, sign posts, light standards, utility poles, and other similar appurtenances should be set back 0.3 meters (1 foot) minimum "shy distance" from the curbing or pavement edge with exceptions for guide rail placement in certain instances. Additional separation distance to lateral obstructions is desirable. Where there is currently insufficient width of paved surface to accommodate bicycle traffic, any placement of these appurtenances, should, where feasible, be set back far enough to allow room for future projects (widenings, resurfacings) to bring pavement width into conformance with these guidelines (Figure 12).

Vertical clearance to obstructions should be a minimum of 2.6 meters (8 feet, 6 inches).

Figure 12

Bicycle Compatible Placement of Appurtenances for Future Projects



Source: Adapted from Bicycle Compatible Roadways, NJDOT, 1982

8. Railroad Crossings

As with other surface irregularities, railroad grade crossings are a potential hazard to bicycle traffic. To minimize this hazard, railroad grade crossings should, ideally, be at a right angle to the rails. This minimizes the possibility of a bicyclist's wheels being trapped in the rail flangeway, causing loss of control. Where this is not feasible, the shoulder (or wide outside lane) should be widened, or "blistered out" to permit bicyclists to cross at right angles (Figure 13).

It is also important that the railroad grade crossing be as smooth as possible. Pavement surface adjacent to the rail should be at the same elevation as the rail. Pavement should be maintained so that ridge build-up does not occur next to the rails.

Other options to provide a smooth grade crossing include: removal of abandoned tracks; use of compressible flangeway fillers, timber plank crossings, or rubber grade crossing systems.

These improvements should be included in any project which offers the opportunity to do so.

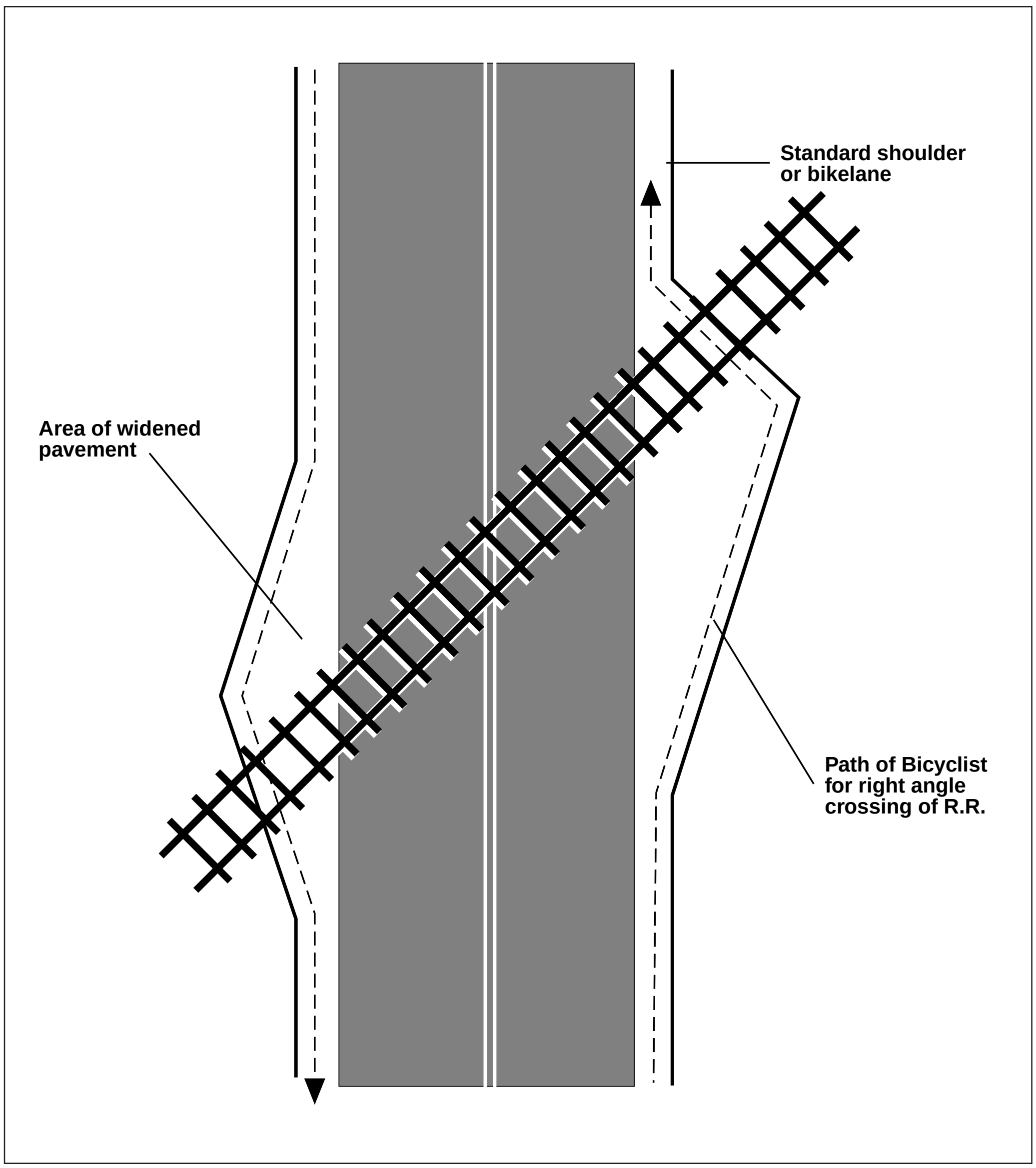


Figure 13

Surface Widening for Bicycles at Non-Perpendicular Railroad Crossings

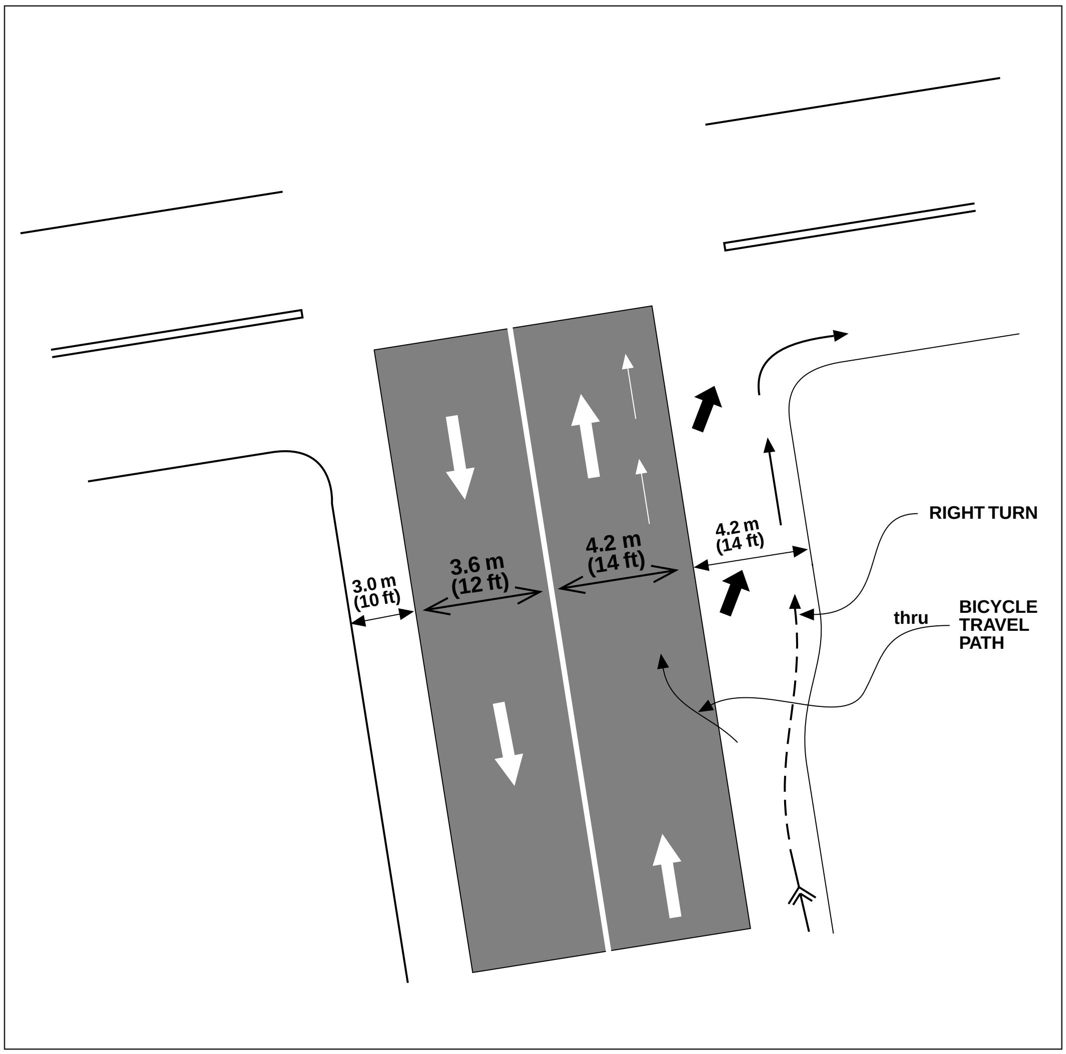
Source: Adapted from Bicycle Compatible Roadways, NJDOT, 1982

9. TSM Type Improvements

Transportation Systems Management (TSM) improvements are minor roadway improvements which enhance motor vehicle flow and capacity. They include intersection improvements, channelization, the addition of auxiliary lanes, turning lanes and climbing lanes. TSM improvements must consider the needs of bicycle traffic in their design or they may seriously degrade the ability of the roadway to safely accommodate bicyclists. Designs should provide for bicycle compatible lanes or paved shoulders. Generally, this requires that the outside most through lane and (if provided) turning lane be 4.2 meters (14 feet) wide (Figure 14). Auxiliary or climbing lanes should conform with Table 1 by either providing an adjacent paved shoulder or a width of at least 4.5 meters (15 feet) (Figure 15). Where shared lanes and shoulders are not provided, it must be assumed that bicycle traffic will take the lane.

Figure 14

Bicycle Compatible TSM Shoulder Converted to Turning Lane



Source: Adapted from Bicycle Compatible Roadways, NJDOT, 1982

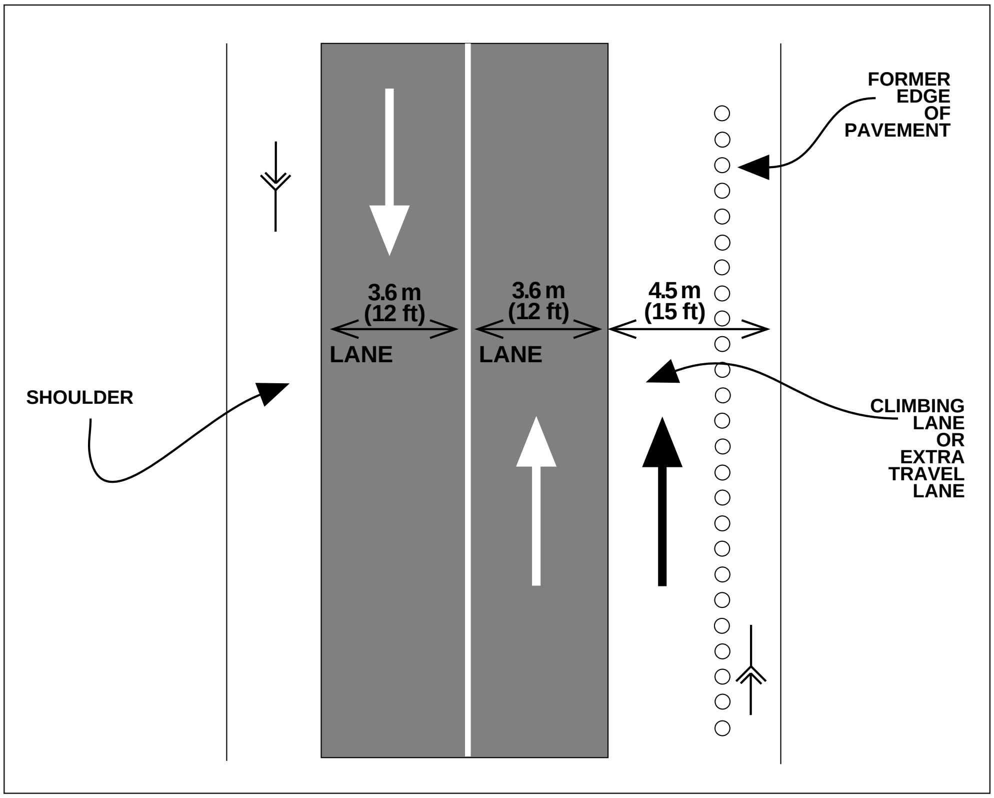


Figure 15

Bicycle Compatible TSM Shoulder Converted to Climbing Lane or Extra Travel Lane

Source: Adapted from Bicycle Compatible Roadways, NJDOT, 1982

10. Marginal Improvements/Retrofitting Existing Highways

There may be instances or locations where it is not feasible to fully implement guidelines pertaining to the provision of adequate pavement space for shared use due to environmental constraints or unavoidable obstacles. In such cases, warning signs and/or pavement striping must be employed to alert bicyclists and motorists of the obstruction, alert motorists and bicyclists of the need to share available pavement space, identify alternate routes (if they exist), or otherwise mitigate the obstruction.

On stretches of roadway where it is not possible to provide recommended shoulder or lane widths to accommodate shared use, conditions for bicycle traffic can be improved by:

- striping wider outside lanes and narrower interior lanes (Figure 16);
- providing a limited paved shoulder area by striping a narrow travel lane. This tends to slow motor vehicle operating speeds and establish a space (with attendant psychological benefits) for bicycle operation.

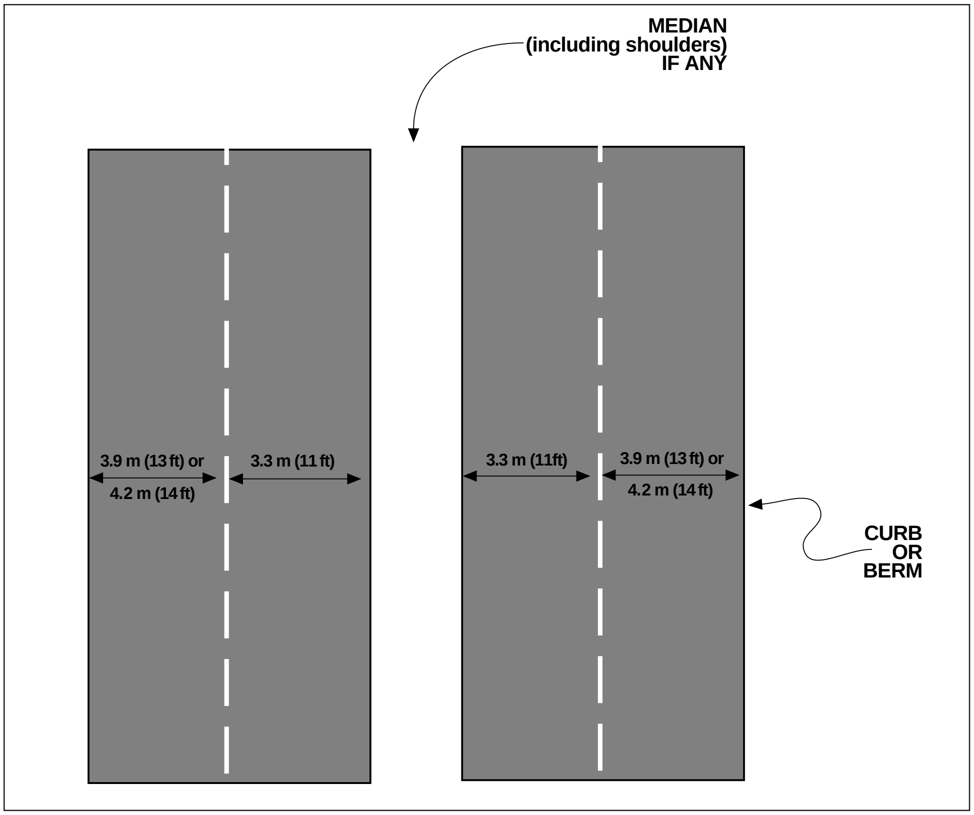
Where narrow bridges create a constriction, "move over" zebra striping should be used to shift traffic away from the parapet and provide space for bicycle traffic (Figure 3).

Other possible strategies, to be employed as appropriate, are shown in Figure 17. These include:

- elimination of parking or restricting it to one side of the roadway.
- reduction of travel lanes from two in each direction to one in each direction plus center turn lane and shoulders.
- reduction of the number of travel lanes in each direction, and the inclusion or re-establishment of paved shoulders.

Figure 16

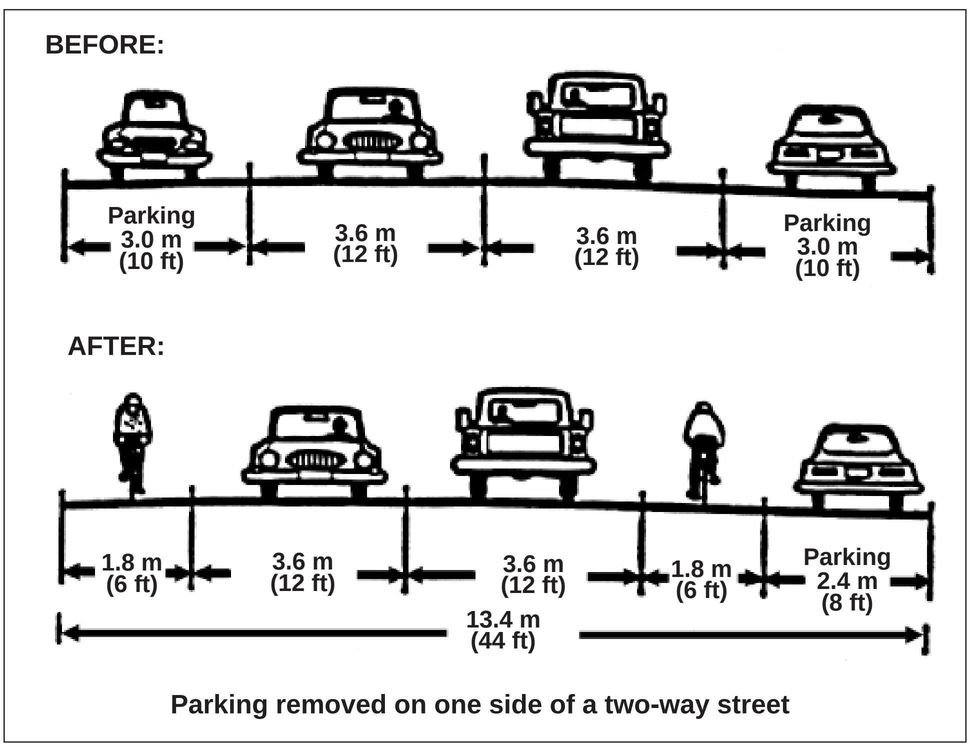
Bicycle Compatible Restriping (Multi-Lane Curbed Section Roadway) (No Shoulder)



Source: Adapted from Bicycle Compatible Roadways, NJDOT, 1982

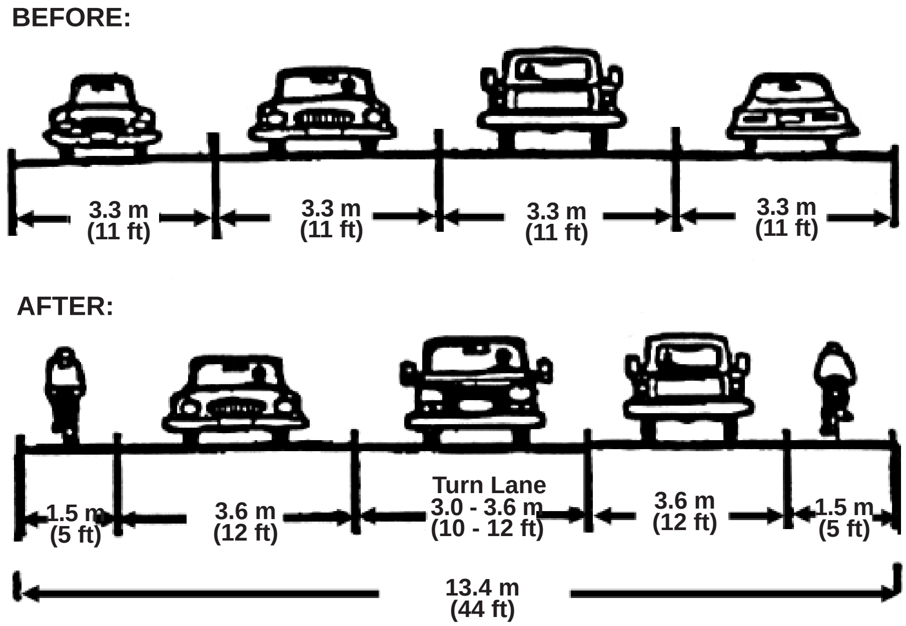
Figure 17

Retrofitting Roadways to Include Bicycle Lanes



Parking removed on one side of a two-way street

Figure 17
Continued



Four lanes reduced to 2 standard lanes, turning lane @ intersections, and shoulders

Source: Adapted from Oregon Bicycle Plan, 1990

11. Permits and Access Control

a. Driveway and street intersections

Frequent access driveways, especially commercial access driveways, tend to convert the right lane of a land service highway and the shoulder area into an extended auxiliary lane for acceleration and deceleration. Frequent turning movements, merging movements and vehicle occupancy of the shoulder can severely limit the ability of bicyclists to utilize the roadway. As a result, access control measures should be employed to minimize the number of entrances and exits onto highways. For driveways having a wide curb radius, consideration should be given to marking a bicycle lane through the driveway intersection areas. As with other types of street intersections, driveways should be designed with sufficiently tight curb radii to clearly communicate to motorists that they must yield the right-of-way to bicyclists and pedestrians on the roadway.

b. On-site circulation and facilities

Entrance and exit driveways should be sufficiently wide to accommodate bicycles. Lane widths for shared lanes presented in Table 1 should be incorporated into the design of all driveways. In general, shared lane use of driveways will be more appropriate than use of a shoulder because of the low speed of traffic on a driveway, the relatively low traffic volumes and the frequency of intersections with parking aisles.

Review of developments for transportation impacts should address how on-site bicycle facilities are planned. Bicycle storage racks should be provided at commercial facilities at locations convenient to building entrances and covered from the elements. This is especially important at retail and service establishments. At employment sites, secure bicycle racks and/or lockers should be provided. For a further discussion regarding bicycle storage facilities, see Chapter 5 - Supplemental Facilities.

c. Reconstruction responsibilities

Construction activities controlled through the issuance of permits, especially driveway, drainage, utility or street opening permits, can have an important effect on the quality of a roadway's surface in the portion of the roadway where bicyclists operate. Permit conditions should ensure that pavement foundations and surface treatments are restored to their preconstruction condition, that no vertical irregularities will result, and that no longitudinal cracks will develop. Strict inspection and control of construction activities is required, and a five year bond should be held to assure correction of any deterioration which might occur as a result of faulty reconstruction of the roadway surface. Spot widenings associated with new access driveways frequently result in the relocation of drainage grates. Any such relocation should be designed to close permanently the old drainage structure and restore the roadway surface. New drainage structures should be selected and located to comply with drainage provisions established in these guidelines.

12. Traffic Calming

a. What is "traffic calming?"

Traffic calming is a relatively new and very different approach to managing the roadway environment. Traffic calming seeks to reduce the dominance and speed of motor vehicles. It employs a variety of techniques to reduce vehicle speeds. Measures can include physical alterations to the horizontal and vertical alignment of the road and changes in priority. In some cases it may be possible to introduce a 30 km/h (20 mph) zone as part of a package of measures. First developed and applied in several European countries, the principles and techniques of traffic calming are arousing considerable interest in the US today. Traffic calming has been used in the US, to retrofit existing residential neighborhoods suffering from excessive through-traffic and in the design of new planned developments. Some techniques employed to calm traffic are familiar to US traffic engineers, others less so. What is different about traffic calming is its use as an overall integrating concept in designing for pedestrians and bicyclists over large areas. Traffic calming is rapidly being seized upon by many local communities and interest groups as an integrated alternative to conventional road planning and design. Its implementation is bound to be controversial because traffic calming reverses and challenges many currently accepted approaches to roadway design.

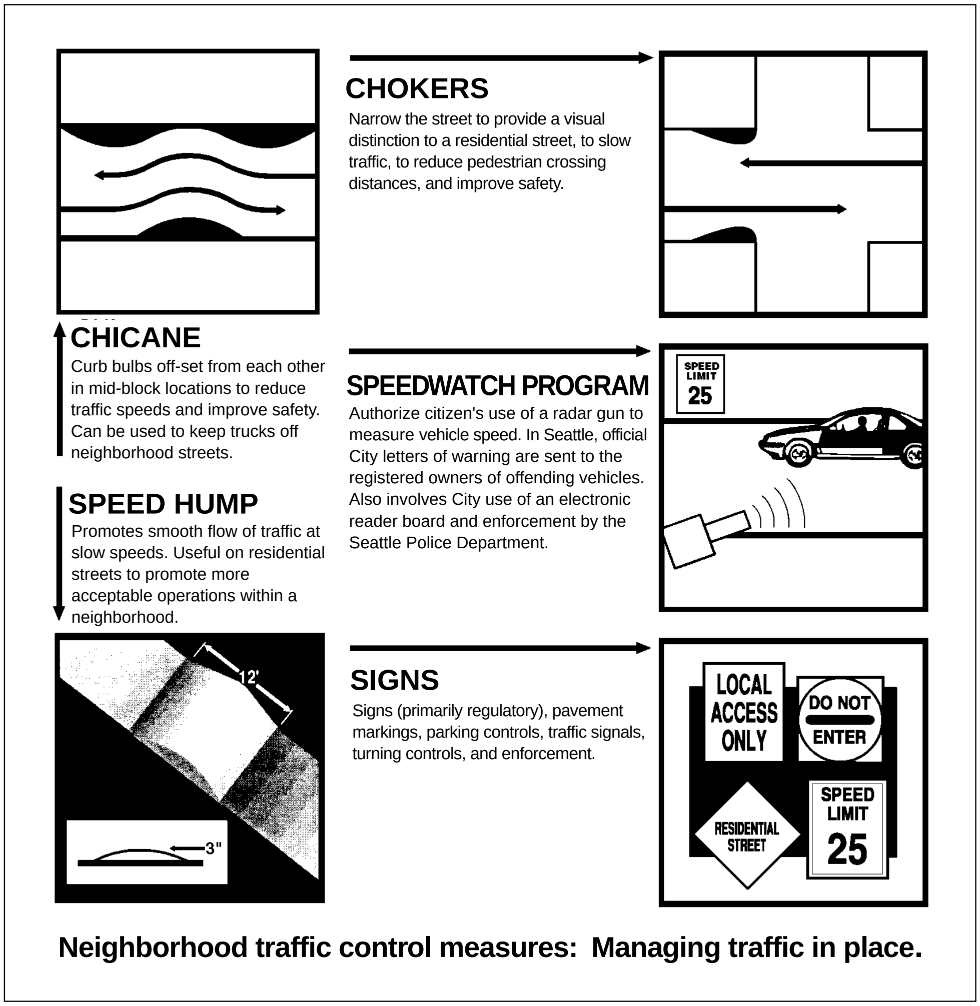
Aside from accident and casualty reduction, the benefits claimed for traffic calming are manifold. Slower vehicle speeds can create better driver discipline; less acceleration and braking reduces fuel consumption, vehicle emissions and noise intrusion. Furthermore, the smoother flow of vehicles may actually improve travel times. Traffic calming also provides an opportunity for environmental improvements. Aside from a reduction in noise and air pollution from motor vehicles, aesthetic improvements such as plantings can easily be incorporated into a program of physical alterations to the road space.

In residential areas, traffic calming is frequently applied to foster the concept that roads are "living areas" and should therefore be made safe and attractive. Here particularly, changes to the street scene are applicable, and, where possible, traffic calming should provide community areas, including play spaces and places where people can sit and chat.

Traffic calming need not, however, be confined only to minor roads. In urban and suburban areas, arterial streets and highways carrying fast, heavy traffic generally pose the greatest danger to vulnerable user groups. Measures that reduce the speed and dominance of motor vehicles and facilitate safe passage for bicyclists and pedestrians are thus even more necessary on such main roads. However, the techniques seen as applicable to main urban thoroughfares generally differ from those employed to calm traffic on minor residential roads. A greater variety of features have been developed for minor roads where stricter speed control is unlikely to adversely affect roadway capacity or levels of service.

Figure 18

Traffic Calming Techniques



Source: Design and Safety of Pedestrian Facilities, ITE, 1994

Normally, traffic calming should be applied as an area-wide technique. To apply it only to a particular street can easily shift accidents, pollution and traffic into neighboring areas.

In order that traffic calming may realize its full potential in terms of creating a safer and more attractive urban environment, it must be part of a wider and longer-term strategy to reduce dependence on private motor vehicles in towns and cities, and promote a modal shift in favor of walking, cycling and public transit.

The growing popularity of traffic calming is attributable to four perceived benefits:

- A significant reduction in road accidents and their severity.
- A greater feeling of security, particularly among vulnerable road users.
- Reclamation of roadway space for non-traffic activity such as play and social interaction.
- Improved visual and aesthetic environments created by landscaping and a reduction in the intrusive presence of motor vehicles.

b. Traffic Calming and Bicyclists

In areas subject to traffic restraint or low speed limits, special facilities for bicycles are not usually needed or provided since traffic calming offers many inherent benefits for bicyclists. Mixing with slower traffic, bicyclists can move around in comparative safety. Traffic calming also offers a more bicycle-friendly alternative to wholly pedestrianized streets. Some traffic calming measures may also be particularly appropriate on older and narrower streets, which are too narrow to allow for the provision of special bicycling facilities.

Nevertheless, poorly-designed traffic-calming facilities can inconvenience or even endanger bicyclists. Bicyclists are particularly susceptible to changes in surface height and texture, and may be put at risk by poorly-considered road narrowing. Speed-reducing measures should not be so "harsh" as to discourage bicyclists from using traffic-calmed areas.

c. Design Guidelines to Accommodate Bicyclists

To avoid losing the inherent benefits of traffic calming for bicyclists by pushing them onto busier routes, the following general design guidelines should be followed in the implementation of traffic-calming schemes.

Figure 19

Bicycle Slip-thru Speed Hump

Source: Cyclists and Traffic Calming, 1982

- Where possible, provide bicyclists with alternatives to by-pass physical obstacles such as *chicanes* or ramps; the recommended minimum width for a bicycle pass is 690 millimeters (27 inches).
- Where a reduction in roadway width is employed as a speed control measure, careful consideration should be given to how motorists and bicyclists can safely share the remaining space.
- Surface materials, particularly on ramps, should have a good skid resistance, while textured surfaces should not be so rough that they endanger the stability of bicyclists or cause severe grazing if the bicyclist should fall.
- A smooth transition on entry and exit ramps should be provided. Inclines should be clearly indicated and have a gradient of not more than 1:6 (16%).
- If the traffic-calming feature (or, indeed, any other traffic-management feature) is to be installed on a road with a gradient, it must be noted that bicyclists are likely to approach it at quite different speeds uphill and downhill. This should be taken into consideration in designing the feature.

Three general observations should be noted from successful traffic-calming schemes that have been implemented:

- Where consistently low speeds less than 30 km/h (20 mph) are required, such as in residential areas, physical traffic-calming features should be positioned sufficiently close together to deter unnecessary acceleration and braking.
- The use of appropriate signing is important to remind drivers that they are entering a traffic restraint area; public awareness campaigns facilitate the acceptance of lower speeds.
- Sympathetic speed limits, such as 30 km/h (20 mph) in residential areas, are used to reinforce the physical speed control measures.

d. Traffic Calming Techniques

Examples of traffic calming techniques are listed and illustrated in Figures 18 through 23. More detailed illustrations and descriptions can be found in the companion document to these guidelines, NJDOT Pedestrian Compatible Planning and Design Guidelines. These techniques are a selection of some current measures employed. Similarly, the descriptions of the various features are for illustrative purposes and should not be interpreted as rigid design criteria. It is recognized that the appropriate application of different traffic-calming techniques is dependent on the physical setting. As a result, the selection of appropriate techniques requires application of professional judgement and creativity.

Road Humps and Speed Tables

***Description*:** Raising the surface of the road over a short distance, generally to the height of the adjacent curb. Humps are longer than speed bumps and can be round or flat topped; the latter are known as "speed tables" and can extend over 3.0 to 9.1 meters (10 to 30 feet). Humps may extend curb-to-curb, or may be cut back at the curb by 200 millimeters (8 inches) with tapered sides to facilitate drainage and permit a bicycle bypass.

Source: Traffic Calming, CART, 1989, STOP, 1993

Figure 20

Speed Table

While generally employed on residential roads, humps are permitted on main roads subject to a speed limit of 50 km/h (30 mph) or less. On higher speed roads, these concepts may still be appropriate to call attention to important pedestrian crossings or areas of congestion. However, care must be taken in design to provide appropriate vertical transitions.

Speed tables frequently are coincident with a pedestrian crossing.

Design Considerations: To ensure the effectiveness of road humps while enabling bicyclists to negotiate them with a reasonable degree of comfort:

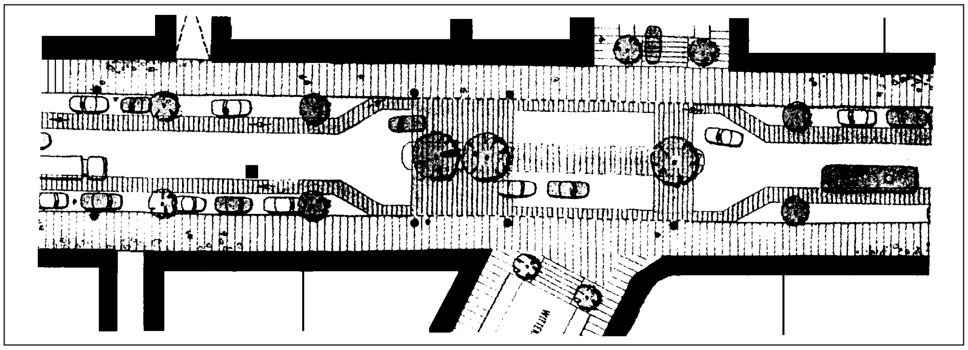
- gradients on the approach and exit slopes should not exceed 1:6 (16%);
- ramp faces should be clearly indicated;
- all materials employed should be skid resistant;
- the leading edge of ramps should be flush with the road surface;
- humps should be situated sufficiently far from an intersection to allow turning bicyclists to regain an upright position before they encounter the obstruction.

Where flat top humps (speed tables) are coincident with a pedestrian crossing they should extend from curb-to-curb.

Speed humps in the vicinity of bus stops should be designed to permit buses to either completely clear the raised roadway or to straddle the hump. (Bus passengers are particularly vulnerable to the adverse effects of humps.)

Figure 21

Mix of Traffic Calming Elements



Source: Traffic Calming, CART, 1989, STOP, 1993

Chicanes

***Description*:** Physical obstacles or parking bays staggered on alternate sides of the roadway so that the route for through vehicles is tortuous.

Design Considerations: In the implementation of chicanes, consideration should be given to the safe passage of bicyclists. This could be achieved by permitting them to by-pass chicanes; alternatively, signs to indicate directional priority may help. Similarly, chicanes must be designed to allow vehicles with large turning radii to negotiate the roadway. To permit street cleaning equipment to operate effectively, the curb radius should always be at least 0.9 meters (3 feet).

A reduction in sight distance should not be used in isolation to reduce speeds, as alone this could be potentially dangerous. A reduction in sight distance may be appropriate to avoid excessive land or ROW takings or as a reinforcing measure only where other physical features are employed which will effectively reduce operating speed.

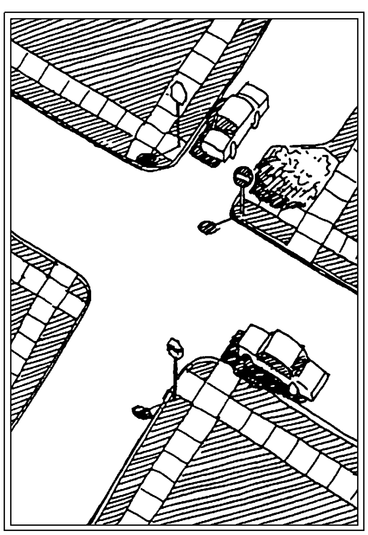
Chicanes offer a good opportunity to make environmental improvements through planting or landscaping. However, preference should be given to low-lying or slow-growing shrubs to minimize maintenance and ensure a reasonable degree of visibility.

Measures should be employed to ensure that chicanes are clearly visible in the dark.

Traffic Throttles/Chokers or Neck-downs

Figure 22

Choker/Neckdown



Chokers/Narrowing/"Neckdowns"

***Description*:** The narrowing of a two-way road over a short distance to a single lane. Sometimes these are used in conjunction with a speed table and coincident with a pedestrian crossing.

***Design Considerations*:** Throttles are generally only appropriate where traffic flows are less than 4-5,000 vehicles/day. Above this level considerable delays will occur in peak periods.

To reduce the risk of bicyclists being squeezed, throttles should generally be used in conjunction with other speed control measures, such as a speed table at the narrowing. Slower-moving drivers will be more inclined to allow bicyclists through before trying to pass. Where bicycle flows are high, consideration should be given to a separate right-of-way for bicyclists at the pinch point, possibly by means of a not-quite-central refuge.

Clear signing should indicate traffic flow priorities.

A textured surface such as blockwork may be used to emphasize pedestrian crossing movement. Substituting this for the normal roadway surface material may also help to impress upon motorists that lower speeds are intended.

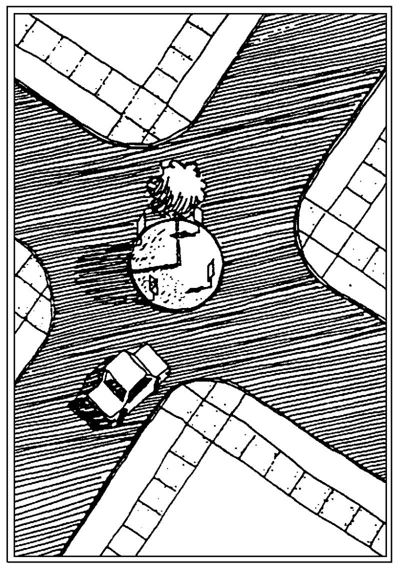
Nevertheless, such measures should not confuse pedestrians with respect to the boundary of the roadway area over which due care should still be taken, especially where a road is raised to the level of the adjacent walkway. As with all crosswalks, appropriate care must be taken to alert the blind and others with limited vision of the presence of a crossing. A tactile material should be provided at the approach which can be detected with long cane techniques. Similarly a contrasting color and texture should be provided for the benefit of the visually impaired.

Roundabouts or Traffic Circles

***Description*:** Small radius traffic circles located at street intersections or mid-block locations. Some have raised centers, others are little more than painted circles on the road.

Design Considerations: Roundabouts should preferably have sufficiently raised and highly visible centers to ensure that motorists use them correctly rather than over-running. Frequently, roundabouts with an interior area greater than 7 square meters (75 square feet) are planted. Small roundabouts may be only painted islands with a flexible barrier.

Complementary speed reduction measures, such as road humps on the approach to roundabouts can improve safety. Clear signing is essential.



Traffic Circles

Figure 23

Traffic Circle

The design of roundabouts must ensure that large radius vehicles will be able to negotiate the roadway, in particular, garbage trucks, fire engines, moving vans and school buses, all of which can be anticipated in residential areas. However, on low speed streets with AADT less than 2000, it is appropriate to assume that these large vehicles can encroach into the opposite lane when entering or exiting a roundabout.

Raised Intersections

***Description*:** The roadway is raised at a street intersection with a visible roadway ramp on each approach. The platform created in the intersection is elevated to curb level and should have a distinctive surfacing.

Physical obstructions such as bollards or planters can be used to restrict the area to which vehicles have access.

***Design Considerations*:** Roadway ramps should not exceed a maximum gradient of 1:6 (16%).

Distinctive surfacing materials should be skid resistant, particularly on inclines. Ramps should be clearly marked to enable bicyclists to identify and anticipate them, particularly in conditions of poor visibility.

As with all crosswalks, care must be taken that visually impaired people have adequate cues to advise them of the roadway area. Tactile strips may be appropriate and color variation will aid those who are partially sighted.

Plug “No-Entry” (with Bicycle Slip)

***Description*:** A cul-de-sac created by blocking access in one direction at one point in the street to motor vehicles. Unlike a traditional cul-de-sac, a “plugged” street remains open for use by bicyclists and pedestrians.

Design Considerations: Bicycle exemption should be provided as a general rule, and designed to minimize the likelihood of obstruction by parked vehicles.

Signing should acknowledge the continued existence of the route as a through one for bicyclists.

Irregular or Textured Surfaces

Description: The use of non-asphalt roadway surfaces such as brick, paving blocks or blockwork, cobblestones to reinforce the concept of a “traffic restricted” area.

Design Considerations: Care must be taken in the choice of materials to ensure that they do not pose a danger or deterrent to bicyclists and pedestrians. Cobblestones present special difficulties and are particularly discouraging for bicyclists on steep slopes because they make it harder to maintain momentum when riding uphill. Similarly, paving stones with chamfered edges impair a bicyclist’s stability and should be avoided.

Cobblestones or other rough surface should not be used along pedestrian routes since they represent both an obstacle and a danger for persons in wheelchairs, walkers or other devices.

In residential areas consideration must be given to the noise that might be generated from textured surface materials.

Tortuous Roads

***Description*:** Roads designed to meander, occasionally turning sharply, reducing the image or perception of a straight and open road, thereby encouraging low vehicular speeds.

This technique is often used in new housing developments, incorporating courtyards or cul-de-sacs and thus removing through traffic.

Design Considerations: Tortuous roads are generally planned during the design of a new road rather than superimposed on an existing one. The siting of buildings may be used to accent the meanders.

Designers should be aware of the need to assure accessibility to residential properties, both in terms of emergency vehicles and service vehicles. Tortuous roads will not be viable if they severely restrict accessibility.

“Woonerf” or Shared Surfaces

Description: The traditional distinction between pedestrian space and vehicular space is removed and a “living courtyard” or common area is shared by both pedestrians and vehicles.

This technique is common in European communities and is created by narrowing the street entry on either end, typically on short, isolated residential streets, and installing obstacles such as planters, parking, etc., at irregular intervals to slow traffic.

Design Considerations: Woonerfs are generally acceptable for short distances only and should be used in conjunction with other physical speed control features such as textured pavement or posted 10 to 15 km/h (8 to 10 mph) speed limit signs.